The development of a fodder radish suitable for multiple grazing

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Abstract

The breeding of the unique smooth-leaved, low-crowned, late-flowering fodder radish, Ceres Graza, is described. It originates from a complex series of crosses and selections carried out over 17 years for smooth leaves, an ability to recover from multiple grazing and for late-flowering habit. Its pedigree traces to vegetable garden radish (*Raphanus sativus*), cabbage (*Brassica oleracea*) and perennial seaside radish (*Raphanus maritimus*). This radish will tolerate repeated grazings and persist for longer than the widely used leaf turnips crops. Its palatability, yield and quality under grazing compares favourably with leaf turnips yet it is able to persist for more cycles of grazing. Compared to both rape and leaf turnip crops it builds up a larger underground root reserve to give it a potential resilience under difficult conditions and an ability to respond to high fertility conditions. Unlike any previous radish cultivars it offers the potential to be used as a pure stand or in mixtures with brassicas or pasture herbs in grazing systems.

Additional key words: Raphanus, hybrid Brassica, breeding programme.

Introduction

Brassicas are widely used as fodder crops on farms and a wide range of species and types are available to cover a range of seasonal uses on farms. Historically these brassicas were grown as a crop for single grazing, however, in the last 40 years European brassica breeders developed leafy turnip and rape cultivars with the potential for multiple grazings.

The genus *Raphanus* or radish is closely related to the *Brassica* genus and offers many of the same characteristics (Stewart 2002). However, radish has had a limited use as a fodder plant and then only in the last 40 years. The leafy types used for grazing have been developed from annual oilseed types to provide a rapidly growing single graze leaf crop (Johnston, 1963, 1969, 1977). Also a large bulb type of Japanese radish is widely used in South Africa as a single graze forage (Rethman and Heyns, 1987; Verschoor and Rethman, 1992), but all these forms are of limited value in New Zealand due to their early flowering.

Radish advantages over Brassicas

The radish genus (*Raphanus* sp) has many interesting features which make it a useful plant not least of which is its rapid development. Many parts of the plant are used as a vegetable including the bulb, leaf, seedpod and sprouted seed. The seed has also been used for the extraction of oil and in the last 40 years it has been used to a limited extent in New Zealand for grazing where it has earned a reputation for its rapid leaf development giving high leaf yields usually greater than brassica crops within 8 to 12 weeks of sowing (Mortlock, 1975).

Compared to Brassica crops radish establishes more rapidly under hot dry summer conditions as well as showing tolerance to the turnip virus complex, turnip mosaic virus, cauliflower mosaic virus and beet western yellows virus which can be devastating on turnips in New Zealand.

However, despite such valuable features traditional radish cultivars have a number of

limitations for use as a grazing forage. The cultivars available are early to flower and forage quality declines rapidly as flowering progresses. For this reason they lack grazing flexibility as they can not be kept for later grazing. During the 1950s and 1960s when the virus problem was particularly severe on turnips, radishes were trialled as a substitute but were found to be more prone than turnips to early bolting and to frost damage (McLeod, 1962; Claridge, 1972). A later flowering bulb type was found to be more promising than these early flowering types, with the additional feature that the radish was more palatable than turnips for sheep (Johnston, 1997).

In addition commercial cultivars usually have prickly leaf and stem trichomes, or hairs, which can limit their palatability and most do not have the ability to regrow after grazing as the growing point is usually removed. These characteristics further limit their widespread use in livestock grazing systems.

In the closely related Brassica genus the fodder turnips, rape, kale and swedes have a biennial habit allowing them to develop large bulks of feed before commencing flowering in spring. The development of biennial radishes would allow a radish crop to build up even larger yields and be kept until needed for grazing, in a manner comparable to turnips, rape, kale and swedes.

Interestingly within the Raphanus genus material with a vernalisation requirement is known in Japan (Nakamura, 1985), but this material is not as late as the very late flowering winter garden radishes, notably Black Spanish material (George and Evans, 1981) or *Raphanus maritimus* (McNaughton, 1976).

The presence of plant trichomes can be a disadvantage to grazing palatability and it would be desirable to have cultivars lacking trichomes. Glabrous germplasm free of trichomes occurs in *Raphanus*, notably in the Asian leafy vegetable form Lobak, a North African line (Johnston, 1977), as well as a cabbage backcross population from Bulgaria (Bonnet, 1979).

The availability of such germplasm creates the opportunity to breed a late flowering biennial fodder radish lacking plant hairs or trichomes. However, there were no reports of *Raphanus* germplasm which will recover from grazing to develop useful regrowth for further grazing.

Radish breeding objectives

In 1987 a breeding program was started to combine these features of very late flowering and smooth leaves into a single cultivar. At this stage it was not appreciated that some radish germplasm could recover from grazing to offer the potential for multiple grazing. By 1997 it became apparent that germplasm derived from *Raphanus maritimus* offered the potential for multiple grazing as it had the ability to regrow from basal nodes on its very low crown.

The Germplasm

The necessary features to develop an extremely late flowering hairless and multiple grazing radish were available in 3 separate *Raphanus* lines as follows (also see Table 1):

Table 1.

Feature	*Raphanus maritimus*	*Raphanus sativus*	
		Black Spanish	Glabrous germplasm
Very Late flowering	+	+	-
Multiple growing points	+	-	-
Deep crown	+	-	-
Forked root	+	-	-
Persistent for 2 years	+	-	-
Regrowth from grazing	+	-	-
Glabrous leaves	-	-	+
Normal Dehiscent pods	-	+	+
Harvestable seed	-	+	+

1. *Raphanus maritimus* is a perennial seaside radish occurring on the sea coast of Europe and southern England. It has some features which are of value for multiple grazing purposes such as the ability to regrow from basal nodes after grazing, a very low crown and a deep forked root. It is also very late to flower and may survive up to 2 or more years. However, it can not be used directly for grazing due to the extreme prickly nature of the trichomes on the leaves and stem. As well as this the silique or pods are non-dehiscent and do not release the seed and must be sown as pod pieces making it difficult to domesticate the plant for modern agriculture. In order to take advantage of the desirable features it was necessary to first cross this species with domesticated *Raphanus sativus* to combine the useful features into one population. These two species had previously been successfully crossed, indicating that no crossing barrier existed between the species (McNaughton, 1976). Another feature likely to be of value from this seaside species is a degree of salt tolerance.

2. *Raphanus sativus* used for commercial production have dehiscent pods enabling a high seed yield. They are also rapid to establish and many cultivars have a high forage yield, albeit from a single grazing. These features are essential for any commercial grazing radish.
    - Within *Raphanus sativus* there is a large variation for flowering time. Most forms are early-flowering but less common late-flowering forms requiring a degree of vernalisation also exist. For a multiple grazing fodder radish late-flowering forms are desirable and a selection for very late-flowering within Long Black Spanish were used as one source of late flowering in this programme.
    - Within *Raphanus sativus* there is a variation in the number of plant trichomes on the leaf and stem. Glabrous forms are more palatable to grazing animals and are desirable for any grazing fodder radish. A glabrous form originated from backcrosses with cabbage (*Brassica oleracea*) (Bonnet, 1979) was used as a source of this characteristic in the program.

Breeding History

To obtain all the necessary features of *Raphanus sativus* of value for a multiple grazing fodder radish it was necessary to cross 2 populations together and select for the desirable features. A very late flowering selection from Long Black Spanish was crossed with the glabrous line to develop the medium late flowering glabrous F3 selection, family A. This selection was then crossed with *Raphanus maritimus* to develop a glabrous F2 selection, family B, an interspecific hybrid line which was very late flowering, glabrous but still with a proportion of non-dehiscent pods. The progeny of each of these two families were further selected for 4 and 3 cycles respectively before being crossed together again to create a new glabrous population, family C.

Over 1,000,000 plants of family C were sown in a 1 ha plot and subjected to intense sheep grazing over a two year period. This resulted in only 10 surviving glabrous plants which had the ability to survive for more than 1 year and to regrow after multiple grazing. In addition to the very late flowering habit, glabrous leaves and dehiscent pods this population had:

- A deep large forked root with a low crown
- Multiple growing points from basal nodes
- Rapid establishment

This population was then selected for a further cycle of selection to stabilise these characteristics before seed increase began.

After 17 years of crossing and selection this has resulted in the selection PG545, now named Ceres Graza.

All crosses were carried out in the field by placing selected plants of one parent among many plants of the other parent and allowing natural cross pollination to occur. A high selection pressure was maintained with between 1000 and 1 million plants being planted in each generation. Each cycle of selection resulted in 7 to 20 parents, which were allowed to inter-pollinate together in isolation.

The resulting selection has a complex origin incorporating germplasm from two *Raphanus* species and one *Brassica* species in the approximate proportions as determined by pedigree; *Raphanus sativus* 86 %, *Raphanus maritimus* 8 % and *Brassica oleracea* 6 %.

Agronomic Potential

Initial trials with Ceres Graza multiple grazing radish have shown a number of promising features. During the course of the breeding programme a number of trials were sown during summer in Canterbury and it was apparent that radish exhibits a more reliable establishment during hot and dry conditions than brassica crops, a result probably due to its large seed and rapid establishment.

An initial trial was sown in November 2000 at Ceres Research station to compare Ceres Graza radish with Winfred rape (*Brassica napus*) and Pasja leaf turnip (*Brassica rapa*) under multiple grazing. This trial was grazed 6 times over the subsequent 14 months. The leaf turnip produced very well for 3 grazings but failed to persist beyond April 2002 as the crop flowered and was subject to the common turnip virus complex. The rape persisted for 4 grazings until September 2001, but failed to survive to any extent after grazing during the bolting stage. The radish, however, survived until January 2002 when the trial was discontinued. At this stage it had survived 6 grazings; showing few signs of virus problems and recovering from grazing at flowering.

In the Hawkes Bay Ceres Graza radish was compared with Hunter and Pasja leaf turnip over a number of grazings in a replicated trial sown on 10th October 2002. The plant numbers of the radish were below that of the leaf turnips after the first cut 39 plants/m^2 compared to 58 and 62 plants/m^2 for Hunter and Pasja due to a lower sowing rate. The DM yield at the first two cuts was less than the leaf turnips but by the third cut the DM yield was greater than the

leaf turnips. The turnips flowered and failed to survive for more cuts while the radish survived for two more cuts to yield 17188 kg DM/ha over the 5 cuts. The average quality of the leaf material was measured as 12.2 MJ/kg DM for the leaf turnips and 12.6 MJ/kg DM for the radish.

The yields are presented in Figure 1. (The 5 % LSD figures for the 3 cuts were 473, 473, 801 kg DM/ha respectively.)

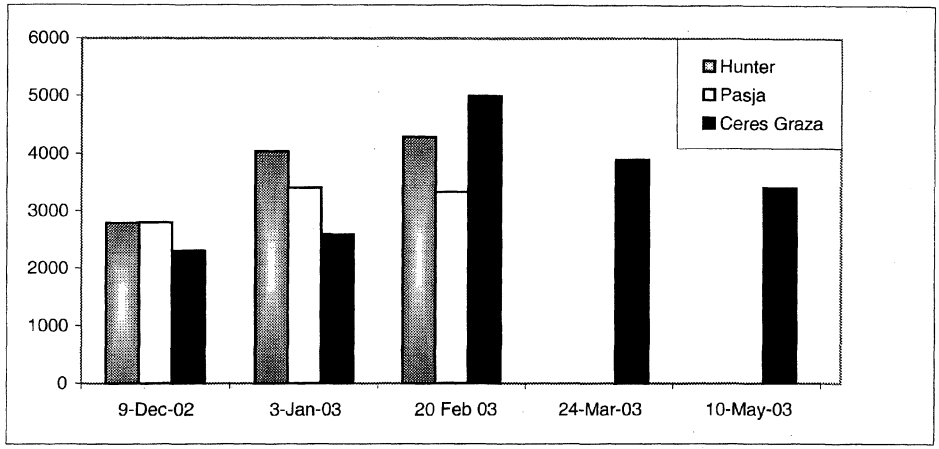

Figure 1. Yield of Ceres Graza radish compared to Hunter and Pasja leaf turnips over 6 grazings.

Results of trials at Lincoln University showed that Ceres Graza was able to produce comparable yields to leaf turnips and rape at each grazing but was more persistent than both. The sheep also showed a preference for the radish over the leaf turnips (Purves, 2003).

Another trial at Ceres Research Centre comparing Ceres Graza with Hunter leaf turnip and Winfred rape sown on 16 Oct 2003 showed that after 9 weeks the leaf yields were within 1 % of each other (2380 kg DM/ha) but the proportion of total dry matter below ground was 10 % for the leaf turnip and rape and significantly greater on the Ceres Graza at 25 %. A similar result was seen in trials at Lincoln University where Ceres Graza produced more underground biomass than the leaf turnips or rape (Hutton 2003). This partitioning of energy into below ground biomass may in turn have contributed to a lower leaf yield at the first grazing, but may also be responsible for its resilience and persistence during later grazings.

Overall, it is apparent that Ceres Graza is capable of comparable DM yields to leaf turnips over 3 grazings and that it is able to persist longer. The yields at the early grazings appear to be less than leaf turnips as it partitions greater energy into its roots, but this is offset by its increased persistence allowing more grazings.

Ceres Graza is later to flower than other commercial radishes and when planted in January few plants will bolt prior to the following spring. However, when planted in early or mid-spring a proportion of plants can bolt to flower during the summer depending on the conditions. However, unlike leaf turnips these can regrow after flowering to provide useful leaf regrowth.

Observations suggest that Ceres Graza crops can be damaged by the first frosts of the season with petioles shattering. Once this is grazed off the new leaves developing after this first frost appear able to tolerate subsequent frosts.

Ceres Graza production has responded well to N applications, irrigation and to high fertility conditions (Jacobs and Ward, 2004). Research on the fertility response is continuing as it is apparent that this species is likely to be more valuable under high fertility systems than under low fertility systems.

Measurements of the SMCO (S-methyl cysteine sulfoxide) content of Ceres Graza radish over 3 years has shown that the level within this radish is below that of comparable brassica crops such as kale, swede, turnips, and leaf turnips grown under the same conditions (Stewart and Judson, 2004). This should reduce the risk of animal health problems caused by SMCO compounds.

Trial plantings of mixtures of Ceres Graza radish with pasture herbs such as chicory and plantain have been made and observational results suggest that the species are compatible in mixtures over many cycles of grazings. Further trials are continuing to determine the role of this radish cultivar under multiple grazing.

Potential use on farms

Ceres Graza radish provides a unique combination of features such as rapid establishment in summer conditions, virus tolerance, high quality forage, persistence under grazing and promising yields. This should allow it to be used in many grazing systems where brassicas are unsuited as well as high fertility grazing systems where high yields of high quality forage are required.

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